IV. *Systematic temperature experiments on some Lepidoptera in all their stages.* By Frederic Merrifield, F.E.S.

[Read December 4th, 1889.]

Plates IV. & V.

The experiments made last year on the effect of temperature upon some Lepidoptera in various stages suggested so many points for further investigation that I determined to pursue my inquiries in a more systematic way this year. Therefore, instead of sending pupæ away to be iced, I provided myself with a refrigerator, in which I ascertained that the temperature ranged during the summer from about 39°, when freshly filled with ice, to about 55° (or even higher in warm weather) when most of the ice had melted; 47° was about the usual summer temperature; in spring and autumn the temperature was sometimes below 39°, and I think about 43° was the average in these seasons. This refrigerator temperature I speak of hereafter as "cool." Inside the refrigerator, however, I had an ice-box, where the temperature was uniformly 33°; this is where I kept the insects spoken of as "iced." I had, besides, two forcing-boxes, and the "forcing" temperature must be understood as about 80° unless otherwise stated.

I had two main objects in view; one to find what exposure to a low temperature could be borne in the different stages, the other to ascertain the effect of temperature, applied in stages anterior to the last, on the colour and markings of the perfect insect, and incidentally I hoped to throw light on some other questions.

As to the first object in view, I hoped the experiments might throw some light on the capability of the insect to pass the season of winter in some different stage from that in which it is now passed. It is well known that

Lepidoptera may hibernate in any of the 4 stages—egg, larva, pupa, or imago; and I wished to ascertain whether those experimented on could be made to hibernate in a stage normally passed in a warmer period of the year.

It is in one or other of the two inactive stages—those of egg and pupa—that I believe the majority of the Lepidoptera, in countries where there is a real winter, pass the cold period of the year, during which for most of them neither food is to be had for the larva nor flowers for such perfect insects as are attracted by them; but the cases in which hibernation takes place in one or other of the two active stages—those of larva and imago—are common, and the capability of passing the winter in a different stage from that in which it has habitually been passed, especially if an insect has a capacity for becoming double-brooded, would, it has been suggested, be a means by which it could adapt itself more readily to the great changes of climate to which the species must have been subjected in past ages. I began with the

Egg Stage.—I believe it is a common opinion that eggs which are usually exposed only to a summer temperature will generally bear severe and protracted cold without injury to their vitality.

Referring to Tables I. and II. appended for details of the experiments made on this point, I limit myself here to a statement of results. In the case of *illunaria* spring-laid eggs, iced in the central "red" stage, 28 days began to affect their vitality, and none hatched after 60 days' icing. The case was worse with spring-laid eggs of *illustraria*, none of which survived 42 days' icing; and some *illustraria* summer-laid eggs were no better. In all the experiments up to 60 days' exposure, and I think beyond that period, nearly all the eggs, after being removed from the ice, matured so far as to admit of the formation of the young larva, which could be seen through the transparent shell; the failure was a failure to hatch.

A curious result happened with some spring-laid *illustraria* eggs iced before they had turned red; two of them became blackish while in the ice (where the eggs were kept for 17 days), and hatched the day they were taken out of the ice, or the next day, the rest remaining red for several days, and hatching in from 11 to 13 days after removal from the ice. These are strong examples of individual character manifested at a very early age. The eggs seemed in all cases uninjured by a temperature of 80°—90°, their development being accelerated by it.

Larval Stage, growing Larvæ.—(1) *Exposure to low temperature.*—Larvæ of *illustraria* in their first skins not exceeding 6 days in age were iced, and all were dead in 20 days; some 30 of the same age, which were cooled, scarcely seemed to grow, but two lived rather more than 63 days. Some that were iced in their second skins were all dead in 21 days. Some that were cooled in one or other of their two last skins grew slowly, four of them spun-up, one as late as the 58th day, and two pupated. In all the cases of cooling the larvæ were supplied with food, which was slowly eaten; in the case of the iced larvæ food did not seem necessary. The experiments seem to indicate that the older larva is more capable of enduring a low temperature than is either the egg or the young larva, and as *illustraria* will live and apparently thrive, at least for a time, on dead leaves, it would seem that this species might hibernate as a larva in countries where the winter is a short one.

(2) *Exposure to a high temperature.*—*Illunaria*, *illustraria*, *autumnaria* (the old *alniaria*), and *alniaria* (the old *tiliaria*), will all bear a continuous temperature of 80°, or a little more, apparently without injury; but one of 90° to 100° is very injurious to them.

Larvæ and pupæ; effect of the temperature to which they are subjected on the colour of the Moth.—The series of *autumnaria* exhibited to the Society last year indicated that temperature in the earlier stages materially affected the colouring and markings of the perfect insect, but left it uncertain whether that effect was produced in the larval or in the pupal stage. As then remarked, they seemed to show either that the larval period was the critical one, or that the colour of the perfect insect could be modified by exposing the pupa to very moderate differences of temperature. I determined this year, so far as possible, to clear up the point, and accordingly tried the systematic experiments I am about to describe. At the suggestion of Dr. Chapman, to whom I am indebted for a supply of eggs of both species, I experimented both with *autumnaria*, as a species belonging rather to the warmer parts of Europe, and *alniaria*, as belonging more to the northern parts. This year, instead of mixing in equal proportions the eggs of several parents, so as to have a better chance of obtaining hereditary varieties, I limited myself to the eggs of a single pair, thus providing more exact means of comparison.

(1) *Preliminary cooling and icing experiments with* illustraria.—Those who are acquainted with Prof. Weismann's studies in heredity as translated and added to by Prof. Meldola, will remember that both in his experiments and in those of Mr. Edwards as recorded in that work, icing was generally not very efficacious unless applied to the pupa in an early stage, and that when so applied it was often fatal. Mr. Poulton's discoveries with regard to the pupæ and pupating larvæ of some of the butterflies showed that the effect of the surrounding circumstances was in them produced only at a still earlier stage, *viz.*, on the larva shortly before pupation. Though there seemed no great reason to suppose that the same principle would apply to pupæ protected by enclosure within leaves, it appeared desirable to test the matter, and to give the icing every opportunity for operating. My first experiments were designed to ascertain whether cold could be borne in the earlier part of the pupating and pupal stages, and, as regards pupæ which would ordinarily pass the pupal stage in summer, what *degree* of cold they would bear as fully-formed and hardened pupæ.

(i) *Icing larvæ just spun up.*—A first experiment with three larvæ of *illustraria* which had recently spun up, and were cooled for 16 days, showed that they had all pupated at that low temperature, and I then determined to try if such larvæ would pupate at the "icing" temperature of 33°. Accordingly (Table III.) I placed 8 in ice just after they had spun up. After 29 days they looked healthy and had spun a few threads, but had not turned; I therefore moved them to the "cooling" temperature, and then in about 6 days 4 of them pupated. These were afterwards iced as pupæ for 42 days; one died and the other three came out as perfect moths. The other 4 were after 8 days' cooling exposed to the ordinary temperature and dry air of the room—about 70° at this time—and all died in a day or two without pupating.

(ii) *Icing larvæ about to pupate* (Table IV.).—Eight which were within a few hours of pupating were iced, and all pupated in from 1 to 6 days, except 1 that died; they were kept in ice 28 days, after which 7 emerged as perfect moths.

(iii) *Cooling and icing pupæ in an advanced stage* (Table V.).—Eighteen were taken at from 7 to 11 days after spinning up, cooled for 2 days, and then iced. Six of them which were iced 28 days seemed quite uninjured, and all but 1 emerged. The other 12 were iced 60 days; nearly all of these failed to emerge or were cripples, 2 of them perhaps necessarily so from want of space to expand their wings.

Several pupæ from sleeved larvæ which were *just on the point* of emerging, but which I wished to keep back, were cooled, and emerged in perfect condition.

(2) *Experiments with pupating larvæ and pupæ of E. autumnaria and E. alniaria.*—The next experiments were tried with these species, which, so far as I know, are never in the natural state subjected to a lower temperature than that of an English summer, averaging about 64°. The experiments were more than preliminary, because they were also directed to ascertain the effect on colour, and therefore will be again referred to under another head, but are here referred to for the sake of indicating their effect on the vitality and healthfulness of those insects in different periods of the pupating and pupal stages. The details will be found in Tables VII., VIII., X., XI., XII., and XV., in the appendix, and the general results may be stated as follows:—Not the least injury seemed to arise from exposing the matured and hardened pupa, the soft green pupa, or the pupating larva to a cooling temperature; and one pupa of *autumnaria*, exposed to a temperature of 33° within 15 hours after pupating, emerged as a moth in good condition. In the case of *alniaria*, 1 that was kept 42 days at 33° came out in good condition, as did 2 that were a little older when iced, and were kept there 50 days. An exposure to 33° for 58 days or upwards proved generally fatal, and always more or less injurious, to *autumnaria*, but I am inclined to think *alniaria* would bear a much longer exposure. An exposure of *autumnaria* for 28 days to a cooling temperature—which must be a much lower one than this pupa is subjected to in its natural

condition—did not seem in the least injurious to it. Cooling the pupating larva, which at an ordinary summer temperature turns in 3 or 4 days, sometimes protracted the period to 14 days.

(3) *General results of preliminary icing experiments.*—These experiments show that not only is exposure to cold in the soft green condition not fatal or necessarily injurious to the species experimented on, but that the pupation of these summer pupæ will take place in some species at the low temperature of 33°, at which temperature therefore the necessary physiological changes must go on, though with extreme slowness. A curious proof is afforded of the harmlessness of the exposure to cold of soft green pupæ of *illustraria* by the exhibition I make of the pupa-cases of 3 that pupated at 33°, and the perfect moths which came out of them ; it will be seen by inspection of the former that by lying so long in a soft condition, owing to the slowness with which they hardened at the low temperature, the pupæ became flattened on the lower side like sausages lying on a counter. There are indications that icing, not protracted, may be injurious to the summer pupa of *illustraria* in one stage, and in one stage only—*viz.*, that in which the pupa is going through the period which separates the central lethargic period from emergence ; and it seems not injurious even here, if the exposure is limited to that very last pupal state of all, when the insect is fully formed in the pupa-case, and is only awaiting the usual time of day to emerge as a moth.

On the other hand, the considerable proportion of deaths and of cripples (see the Tables), and the irregularity of the period of emergence after the pupæ were taken out of ice or of the cooling temperature show that long exposure to cold of these *ennomos* pupæ, which have only a summer existence, is very injurious and disturbing to them.

(4) *Systematic experiments as to the effect of temperature on the colour and markings of the imago with* autumnaria.—These experiments were directed to several ends. The first was to ascertain beyond doubt whether it was in the larval or in the pupal stage that the low temperature operated, or chiefly operated, on the colour of the moth, and I think in this respect they have yielded very

clear results. I should premise that in describing the colours, I only mention the broad general effects. I am indebted to Mr. White for the more detailed description which I append. All the experiments were tried with eggs from the same parent.

The detail of the experiments will be found in the Appendix (Tables VI., VII., VIII., IX., X., XI.). Some were forced all through, others forced as larvæ, cooled as pupæ. Some were kept at the ordinary temperature all through; others, having been so kept as larvæ, were divided into two lots, of which one was forced as pupæ, the other cooled or iced for 28 days or more as pupæ. The result may be stated as follows:—*It was in the pupal state that the effect was in the main produced.* The *forced pupæ,* whatever the treatment of the larvæ had been, *invariably produced pale and comparatively spotless moths;* the *cooled or iced pupæ,* whatever the treatment of the larvæ had been, *invariably produced dark and much spotted moths.** Another point, suspected last year, was established—that a temperature of 63°, or even higher, is low enough to produce the well-known dark and spotted appearance. At the same time, the colouring of the moth seems *somewhat* affected by the temperature at which the larva has been brought up. The larval period in those that were forced was about 30 days, the pupal about 16, total 46 days; as against a larval period of about 68 days, and a pupal of about 25 days, total 93 days, in the unforced.

The moths from the forced pupæ are mostly smaller than the others, but this may be an accident, resulting, perhaps, from the circumstance that, owing to a relaxation of vigilance in the beginning of June, they were exposed for 3 days to a temperature of 90°—100°, which caused many deaths.

It will be seen that there is some individual variation, more particularly in the pupæ exposed to the ordinary

* There is little difference in general appearance between the moths from the cooled pupæ of forced larvæ, and the moths from the cooled pupæ of larvæ bred in the ordinary temperature; such as exists is perhaps partly owing to the fact that the latter were exposed generally to a lower temperature (the Refrigerator being colder at the time they emerged), and in some cases for a longer time. It is probably owing to this greater exposure that they have a less vigorous appearance, and include a large proportion of cripples.

temperature, and therefore some of the colouring must be attributable to individual and presumably hereditary qualities; but I do not think any one can look at the moths experimented on without recognising that practically the spotting or the spotlessness of *autumnaria* depends on the temperature to which the pupa is exposed, and that the temperature of an ordinary English summer is low enough to develop plentiful spotting, a difference between 65° and 80° counting for much more in this respect than one between 33° and 65°. So that a continental pupa imported young might be expected to develop the well known spotted appearance of the dark British form; in other words, the dark northern form is not, or at all events may not be, racial, but is the effect of climate on the individual pupa. In this respect the species seems to differ altogether from the double-brooded ones experimented on by Prof. Weismann and Mr. Edwards.

(ii) *With* alniaria (*formerly* tiliaria) (Tables XII., XIII., XIV., XV., XVI.).—I tried on a brood of these, all proceeding from the same parent, the same experiments as on *autumnaria;* but the results on the colouring, though tending in the same direction, were by no means so regular or so striking. This is, perhaps, partly because I bred only 8 of the female sex (which is the one which seems the most affected in this species); the same accidental raising of the temperature, which was so injurious to *autumnaria*, having been still more so to *alniaria*. In those that were forced the larval period averaged 27 days, the pupal 14 days, total 41 days; as against 62 days larval, and 23 pupal, total 85 days, in those that were unforced. The pupating larvæ and pupæ seem to bear cold better than those of *autumnaria;* I bred two perfect males after an exposure for 50 days to a temperature of 33°.

(iii) *With* illustraria.—It will, perhaps, be remembered that last year I showed some *illustraria* of which the summer pupæ had been iced 14 days, with the result that they manifested a very slight change of colouring in the direction towards that of the winter-pupated form. This year I determined to try the effect of exposure to an icing temperature, for periods successively increased by regular steps. I wished to see whether the colouring of the spring emergence could be actually reached, and whether the markings also would change; and, if so, it struck me that it would be interesting to let the insect record, as it were for itself, in the markings of the preserved specimens, the steps by which the change in the markings was effected. Accordingly I brought up a brood from a single pair, from which I obtained 87 pupæ between 17th June and 3rd July. Fourteen were not iced, and previous experiments having led me to observe that there is often some difference in general colouring between the first and last parts of a brood, 8 of these 14 were taken from among those which pupated earliest, and 6 when about two-thirds had spun up. The whole of the 14 emerged in good condition, showing that I had fallen on a healthy brood; and showing also that it was a naturally dark coloured one, and therefore, perhaps, not so well adapted to show any darkening of colour as a lighter coloured set would have been. I had rather gathered, from experiments by others previously published, that about 28 days might be expected to produce full results; and therefore at first I was rather extravagant in the use of my materials, so that the numbers taken from time to time out of the ice had to be greatly reduced when experience showed that a much longer time was necessary to produce full effects in the case of this insect. The fortnightly withdrawals were as follows:—10 pupæ in 2 weeks, 12 in 4 weeks, 4 each in periods of 6, 8, 10, 12, 14 and 16 weeks, and 2 each in periods of 11 and 20 weeks; and I have 14 pupæ remaining, which I hope to spread, if necessary, over another 12 weeks, as this will make up the period of 7½ months, which is the full duration of the usual winter pupational period; this, however, does not seem necessary, as previous experiments lead me to believe that about 5 months is sufficient to produce the full colouring of the spring form under natural conditions, with an average temperature much higher than 33°.

(*a*) *Summer pupa of* illustraria; *effect of icing on vigour.*—Great as is the difference between exposure for two or three weeks to a temperature of 60°—70°, which is what this summer pupa in its natural state would sustain, and exposure of it, as in the experiments last described, to a temperature of 33° for 20 weeks, no injury seems to have been inflicted by this severe trial.

The deaths were very few, apparently not more than would have occurred if the pupæ had not been iced; there were no cripples, and the moths emerged with such perfect regularity that when the temperature in which the pupa was placed after removal remained about the same, I could always foretell within a day when the moth would emerge.

Effect on colour and markings.—As might have been expected, there is no change in size, but I am not sure there is not a slight difference in form caused by the icing, in a less rounded costa and a rather narrower wing. The difference in colour, however, is great, and in markings striking. In colour a general warm brownish hue with a considerable increase of darkness prevails. One of the most striking differences between the ordinary summer and spring form is in the shape of the outline of the dark inner portion of all the wings. In the summer form this outline approaches a *half circle*, but is very sinuous, with a conspicuous *break of continuity* where it passes from the anterior to the posterior wing, caused by curves inwards, and with several angles, of which the most salient is on the anterior wing, near the costa, with the outer portion of which it consequently forms an *acute angle*. In the spring form the dark inner portion approaches the shape of a *half hexagon*, the most salient angle being on the posterior wing, the other angles and curves being straightened out, an *obtuse angle* being substituted for the acute angle on the costa, and the outer edge of this dark part becoming *continuous* from the anterior to the posterior wing. This edge is also more blurred in the iced than in the uniced specimens. The first appearance of these changes in markings was in a female iced 28 days, and after 56 days they became frequent in both sexes, a male of 20 weeks' icing and two females of 18 weeks' seeming the most marked. As may be gathered, the change is not a gradual and regular one from fortnight to fortnight. Still there are some intermediate specimens that appear to show the process of transition—an interesting subject for investigation, which, however, I must leave to those who are better qualified to pursue it. I think it is of consequence to observe that the moth from the iced summer pupa, though there are changes causing it to bear a considerable general resemblance to that which proceeds from the autumn pupa, is not the same in colour or in markings.

(*b*) *Autumn pupa of* illustraria; *effect of forcing, &c., on vigour.*—This converse experiment affords a striking contrast as regards its effects on the vigour of the insect.

Of 36 pupæ so treated in the autumn of 1887 (Tables XVI. and XVII.), only 12 emerged, and of these 7 were cripples, and only 5 perfect, or nearly so; and of these 5, 4 had been exposed some weeks after forcing to severe cold out-of-doors for about 5 weeks before the forcing was resumed.

Of another lot of 63 belonging to a not very healthy brood—for two-thirds of the larvæ died—18 were kept at the moderate temperature of about 60°, and of these only 4 emerged, 2 of them being cripples. The rest, 45 in number, were placed out-of-doors, and of these 32 emerged, only 3 of them being cripples.

Of the pupæ lent me by Mr. Jenner (as mentioned Ent. Soc. Trans., 1889, p. 92), being a brood which, except two individuals, laid themselves up for winter pupation instead of emergence in July, 26 were forced (Table XIX.), and only 13 of these emerged, of which 4 were cripples. This was a very healthy lot, for about 30 of the same brood, which were left to winter in a cool room, nearly all emerged in perfect condition.

All that were thus forced showed great irregularity in the time of their emergence, and they all seemed less thickly clothed with scales than normal specimens are, whether of the autumn pupa or of the summer pupa, the moths from which last are in general the most thickly clothed with scales.

The irregularity caused by forcing the autumn pupa at different periods is illustrated by Table XVIII., relating to a very healthy lot of 20 pupæ. This Table affords evidence that the irregularity is caused by forcing the autumn pupa at a time when it would naturally remain for months in the pupal condition, for the irregularity ceased when the forcing was postponed until the autumn pupa had been 4 months in that state.

Effect on colour and markings.—All the moths are intermediate in colouring and in markings between the summer and the spring emergence. Such as were exposed to cold during part of the pupal period are considerably darker than the rest, and make the nearest approach in colouring, and I think, on the whole, in markings, to the spring emergence. In both classes those that were longest in pupa were, as a rule, darkest, even in the case of such of the pupæ as were never at a lower temperature than about 60°, which seems to indicate that retardation may be a cause of the difference in colour and markings.

(*c*) *Causes of the difference in the two cases.*—These results are so far in general accord with those recorded by Prof. Weismann as regards *A. levana*, and by Mr. Edwards as regards *P. ajax*, as to show a significant difference between the readiness of the summer pupa to bear and be influenced by winter conditions and the resistance offered by the autumn pupa to summer conditions. Prof. Weismann explains this difference by the hypothesis that the winter-pupating generation is the ancient and more firmly established form, and expresses the opinion that other disturbances of the summer pupa, such as extreme heat or mechanical motion, may cause a reversion to the older form. My experiments *seem* to indicate further a *direct* effect of temperature in altering colour, &c., in *both* broods of the seasonally dimorphic *illustraria*, causing the summer pupa to yield a much darker moth and the autumn pupa a much paler one, the darkness or the paleness in either case depending in a great degree on the length of the exposure. And the very marked effects of a similar kind produced on the pupa of *autumnaria*, which I believe is nowhere double-brooded, also appear to indicate a similar direct effect of temperature on colour : I do not know if there is any reason for ascribing it in the case of this species to reversion.

5. *Stage in which temperature most operative.*—There is no doubt a strong predisposition, in an individual belonging to a double-brooded species, at some period of its development, towards one of the two different destinations, *i. e.*, the emerging in the summer and with the summer colouring, or the lying over until the spring and then emerging in the spring colouring. The experiments lead me to think that in the species operated on by me the predisposition has become so decided in the *larval* stage that no treatment of the pupa can afterwards entirely alter it, but that in the early larval stage

treatment can—I do not say in all cases—either give the required predisposition, or, where it exists naturally, can completely reverse it.

Perfect Insects, icing.—From the 20th to the 23rd July I iced 5 male and 2 female *illustraria*, a day or two after their emergence. They were frequently looked at and seemed in a lethargic condition, nearly motionless, reviving, however, immediately in the warm air of the room. By the 15th September, *i. e.*, after about 55 days, they seemed less inclined to move, and I placed them for an hour or two at a cooling temperature, and then in the air of the room, where the temperature was about 64°. One female was dead; 5 males and 1 female were alive and could flutter a little, but only one was able to crawl up the side of the box; and, after keeping them for a day or two, they showed no signs of reviving.

Incidental Matters.—(1) *Male longer in pupa than female.*—The experiments recorded last year indicated that in the species operated on the pupal stage was longer in the male than in the female. With a view to place this matter beyond doubt, I made some exact experiments by noting as closely as I could the time of (1) spinning-up, (2) pupating, (3) emergence, and found myself able to carry out the observations very accurately. They gave the following results:—

autumnaria (forced). Table VI.

	7 males. Days.			9 Females. Days.		
	Longest.	Shortest.	Average.	Longest.	Shortest.	Average.
From spinning-up to emergence ..	17¼	16½	17	15	14	14¼
From pupating to emergence	15½	14½	15	13	12	12½

The extreme regularity of the period of duration in all cases will be noted: the slowest female was considerably ahead of the fastest male. As the males and females emerged at the same time, the male must have been on the average earlier to pupate than the female, from which it follows either that the male feeds up faster than the female, or that the female hatches earlier, a thing quite possible, as the hatching in this species extends over a period of many days. A practical conclusion seems to be that small larvæ of this and similar species pupating early are almost sure to be males, while large ones found late in the season are almost sure to be females.

In some *autumnaria* (Table VII.) that were cooled for a period of 28 days there was a similar difference, only slightly greater, averaging $2\frac{1}{2}$ to 3 days in favour of the female.

In some *alniaria* (Table XII.) the difference was greater still, amounting (in some that had been cooled for 28 days) to an average of 4 days in favour of the female.

In *illustraria*, comparing 25 iced males with 15 iced females, I find that the former averaged 12·2 days from the time of being taken out of the ice, the latter 10·6 days.

(2) *Slow development of the pupa during the icing period.*—My experiments do not enable me to measure this accurately, as the temperature to which the pupæ were exposed, after being taken out of the ice, varied with the varying temperature of the year. As far as I can guess, I should say that 120 days at 33° represent as regards progress in time for development certainly not more than 3 days at 65°.

(3) *Obscurity of the causes on which the vigour of a brood may depend.* — I add some observations on the deterioration in some cases of the heredity broods of *illustraria*, because it is of general importance to all who are bringing up larvæ for scientific and other purposes to get, if possible, at the causes of this deterioration with a view to its prevention. All who have bred on a considerable scale are familiar with it as a frequent result with many species, but by no means with all, especially when care is taken, as it has been with my *illustraria*, to bring them up under the most favourable conditions. The second generation of those bred in captivity, *i. e.*, the larvæ fed in the autumn of 1887, produced remarkably large and healthy moths, the largest I have ever seen. There was some falling off in health and size in the next emergence (July, 1888), and a very great falling off in both respects in the following autumn-fed brood. Since then the health and size have continued with those bred by me to be about the same, that is, poor. But the circumstance I wish particularly to call attention to is that the deterioration in some cases, which I should be glad to account for, has

given place to an opposite result. Some broods, which with me had become a mere remnant, few in number and small in size, produced eggs, which I sent to my friend Miss Pridham, of Wimbledon, who has been rendering valuable aid in these experiments, and these have produced much larger, more numerous, and more healthy moths, and that not in one case, but in several. The only difference that I can see in the treatment is that they have been sleeved on old cherry instead of young birch, and have been in a rather warm situation. But none could have been finer than those I reared on young birch in a cool situation in 1887. After much consideration I cannot see that either interbreeding, kind of food, crowding, temperature, moisture, change of locality, or any other circumstances I can think of, account for the difference. The fact that the deterioration is not continuous is encouraging, and I shall be very much dissatisfied if, with the kind suggestions of members of this Society, the cause of it cannot be ascertained, for the benefit of myself and others. I have always thought that the causes of the wholesale deaths one reads of in narratives of larval bringing up, for example, in the late Mr. Buckler's work, require more investigation than they have received. The only conjecture I can make as to this particular case—and it is a conjecture only—is that possibly *illustraria* requires a change of diet after a generation or two. There are indications of a liking for such change in individuals; larvæ beaten from oak showed with me a decided preference for birch and willow, and some brought up on birch took to rose in their last stage.

Some General Conclusions. — I venture to submit some of the principal conclusions of a general kind to which the experiments recorded in this paper and in previous ones seem at present to point. As to some there will probably be little or no difference of opinion, and as to others, no doubt further experiment is necessary, and their apparent results require also to be considered by the light derived from a knowledge of the habits and life-histories of many other species than I have any experience of. The Tables in the Appendix show in detail the facts as regards each individual in many of the broods operated on by me, with the results stated. They will enable others to judge how far my conclusions appear to be well-founded, and I hope that so many recorded facts, the substantial accuracy of which may be relied on, may prove useful in other ways to some of those who are prosecuting biological researches.

I. *As to seasonal double-brooded species.*—This term is used as a name, not a definition, and in the restricted sense of a species which has two (or more) generations in a year, one of them passing the pupal stage in the winter, the insects belonging to this generation, which I will call the winter type, differing from those belonging to the summer generation, which I will call the summer type, not only in (1) the season of the year during which their existence is passed, and (2) the duration of that existence, sometimes three or four times as long as that of the summer type, but also often presenting differences in (3) size, (4) shape, (5) colour, and (6) markings. (The sense in which I use the term excludes certain species of which I have little knowledge, such, for example, as those which are many-brooded in countries where there is no real winter; also those species which pass the winter in some other than the pupal stage.)

1. In such a species a young individual may have, and often has, a constitutional capacity for developing into either type, according to external circumstances.

2. It seems probable that there is from the beginning of the existence of the individual a tendency, which may be very strong, or very slight, to develop in the direction of one of the two types.

3. If there is no such innate tendency in an individual, it can be imparted by external influences during the early part of its existence.

4. Where the tendency exists, it varies in strength in different individuals. In the case of some species, or some broods or individuals of some species, the tendency from the beginning is so strong that it cannot be overcome by any external influences.

5. In other cases the tendency can be overcome and converted into the opposite one, or turned more or less in the direction of it, by such influences. The *decision* as to the type to be assumed is come to before the termination of the growth of the larva, and this decision may be completely controlled in some cases by external influences applied before that period. For example, in

1887, by keeping the insect in all stages at a temperature of about 80°, I brought out four successive broods of *illunaria* in ten months, all of the summer type.

6. After larval growth is completed, no complete conversion of the one type into the other can be effected; it seems clear that such a conversion cannot be made as regards size, and but slightly, if at all, as regards shape; and it seems probable that it cannot be completely made as regards colour or markings. This incapability as to colour and markings certainly exists as respects *illustraria*, also, according to the published experiments before adverted to, as respects *A. levana* and *P. ajax;* and I gather that in the cases published as to *P. rapæ*, *P. napi*, *P. pharos*, and *P. interrogationis* the butterflies from the iced summer pupæ presented some differences from the normal form proceeding from the winter pupa.

7. In the species experimented on by me (and in some others) the capability of being turned during the pupal period from the one type partially in the direction of the other exists in both the summer and the winter type, but is *much* greater in the former than in the latter.

II. *As to both double-brooded and single-brooded species.*

8. In those experimented on by me the temperature to which the pupa is exposed modifies the colour and markings of the imago, sometimes in a striking manner; low temperature in these species tending to melanism.

9. The difference between 65° and 80° in the temperature to which the pupa is exposed is sufficient in some cases to make a very marked difference. In *E. autumnaria* it is enough to make the whole difference in appearance between the ordinary pale continental type and the dark and spotted type.

I do not see that the experiments in themselves lend any support to the theory that *illustraria*, having originally been a single-brooded species suited to a cold climate, could, as it spread to a warmer region, or as a glacial period receded, pass the winter in any other than the pupal stage, and by that means adapt itself to become regularly double-brooded; for in no stage but this have I been able to carry it alive through even a short artificial winter, and the winters on the hypothesis must have been very long ones. Nor do they appear to help to show how so great a change as that from single-broodedness with its pupa of 7 months or more to double-broodedness with its summer pupa of 2 or 3 weeks could have been made. Assuming the autumn pupa to have been the original one, it must have had an even stronger disposition than the modern seasonal autumn pupa not to emerge until after a winter had passed over it, and the extreme reluctance of the modern seasonal autumn pupa to anticipate its regular period of emergence has been shown. Perhaps the species, or at least the genus, may claim a very high antiquity, and may have lived through several periods of advancing as well as of receding cold; but I cannot pursue this speculation, for I know too little of such matters to venture beyond the solid ground of fact more than the very few steps which are the necessary incentive to further investigation.

Note, 6th March, 1890.—I can now complete the history of the iced summer pupæ of *S. illustraria* mentioned pp. 96—99. I had 12 living on the 28th December, when they had been iced 22 weeks. Taken out at successive intervals of 14 days, 5 of them died, including the 2 taken out at 32 weeks. The survivors show no increase of darkness over those iced 16 or 18 weeks, and have altogether a less vigorous appearance than the great majority of those which emerged after 20 weeks' icing or less; but I am doubtful if the longer duration of the icing is the cause of this deterioration, as the larvæ of this brood that were late in pupating were decidedly less healthy than the earlier ones.

The Roman numerals refer to the months ; "Ord." means ordinary temperature ; "*m*," "*a*," "*e*" mean "morning," "afternoon," "evening."

Table I.—Icing eggs of *S. illunaria.*

Origin.	Iced.	Nr.	Colour	Taken out.	Nr.	Days Iced.	Hatching. Began	Ended	Number.	
♀ taken New Forest	4 v	34	Red.	18 v	16	14	25 v	27 v		16
				1 vi	16	28	6 vi	......	5	
							7 vi	......	8	
							8 vi	......	1	14
♀ taken Scarborough	4 v	38	Red.	15 vi	4	42	20 vi	22 vi	....	3
				29 vi	6	56 }				
				30 vi	12	57 }	5 vii	......	....	7
				9 vii	10	66	......	......	....	0

Table II.—Icing eggs of *S. illustraria.*

Origin.	Laid	Nr.	Iced.	Nr.	Colour	Taken out.	Nr.	Days Iced.	Hatching. Began	Ended	Number.	
Bred parents	5 v	251	(not iced)	41					23 v	26 v		36
Same parents	6-7 v	....	7 v	30	"Green."	24 v	30	17	24 v	......	1	
									25 v	......	1	
									4 vi	......	6	
									5 vi	......	10	
									6 vi	......	3	21
			7 vi	140	Red.	24 v	20	14	31 v	2 vi	....	19
						7 vi	9	28	14 vi	......	4	
									15 vi	......	3	7
						21 vi	10	42	......	......	....	0
						1 vii	20	52	......	......	....	0
						6 ix	20	58	......	......	....	0
Bred parents	19-22 vii	110	1 viii	110	Red.	6 ix	40	36	......	......	....	1
Summer emergence }	....	....	....	....	....	14 x	25	74	......	......	....	0

Table III.—Preliminary icing experiments on *S. illustraria*. Larvæ just spun up.

No. of ♀ parent.	Sp. up.	Iced.	Cooled	Pupated.	Iced.	Taken out.	Emerged	Sex.	Days. Pupating. Iced.	Days. Pupating. Cooled	Days. Pupa. Iced.	Days. Pupa. Ordy.	
"Red" 11	23 vi	23 vi	22 vii	28 vii	29 vii	30 vii	Died.	..	29	6	1	..	
,, 12	,,	,,	,,	,,	,,	9 ix	24 ix	♂	29	6	42	15	
,, 51	30 vi	30 vi	22 vii	....	......	30 vii	died 1 viii	..	22	..	..	..	
,, 52	,,	,,	,,	....	......	,,	died 1 viii	..	22	..	..	..	
"Dark" 28	23 vi	23 vi	22 vii	28 vii	29 vii	9 ix	25 ix	♂	29	6	42	16	
,, 29	,,	,,	,,	,,	,,	,,	23 ix	♀	29	6	42	14	Crippled.
,, 73	30 vi	30 vi	22 vii	....	......	30 vii	died 1 viii	..	22	8	..	2	
,, 74	,,	,,	,,	....	......	,,	died 1 viii	..	22	8	..	2	

Deaths probably caused by sudden removal to warm, dry air.

Table IV.—Larvæ of *S. illustraria* on the point of pupating.

No. of ♀ parent.	Sp. up.	Iced.	Cooled	Pupated.	Taken out.	Emerged	Sex.	Days. Pupating. Ordy.	Days. Pupating. Iced.	Days. Pupa. Iced.	Days. Pupa. Ordy.
"Red" 1	21 vi	23 vi	......	26 vi	25 vii	6 viii	♂	2	3	29	12
,, 2	,,	,,	......	27 vi	,,	,,	♂	2	4	28	12
,, 43	29 vi	30 vi	......	6 vii	3 viii	17? viii	♀	1	6	28	14
,, 45	,,	,,	22 vii	1 viii	30 vii	died 1 viii	..	..	..	..	..
"Dark" 13	22 vi	23 vi	......	26 vi	25 vii	8 viii	♂	1	3	29	14
,, 14	,,	,,	......	24 vi	,,	6 viii	♂	1	2	31	12
,, 63	29 vi	30 vi	......	4 vii	1 viii	16 viii	♂	1	4	28	15
,, 65	,,	,,	......	5 vii	2 viii	17? viii	♂	1	5	28	15

No. of ♀ parent.	Sp. up.	Cooled	Iced.	Taken out.	Emerged	Sex.	Days. Ordy.	Cooled	Iced.	Ordy.	
"Dark" 2	19 vi	30 vi	7 vii	5 ix	5 ix	♂	11	7	60	0	Crippled, not room to expand.
,, 3	,,	,,	,,	,,	Died.	..	11	7	60		Crippled, not room to expand.
,, 4	,,	,,	,,	,,	3—5 ix	♂	11	7	59	0	Crippled, not room to expand.
,, 11	21 vi	30 vi	7 vii	5 ix	Died.	..	9				
,, 15	22 vi	,,	,,	,,	Died.	..	8				
,, 16	,,	,,	,,	,,	Died.	..	8				
,, 33	24 vi	5 vii	7 vii	4 viii	9 viii	♂	11	2	28	5	
,, 34	,,	,,	,,	,,	14 viii	♀	11	2	28	8*	
,, 45	26 vi	,,	,,	5 ix	10 ix	♀	9	2	60	5	Crippled.
,, 54	27 vi	,,	,,	,,	12 ix	♂	8	2	60	7	Crippled.
"Red" 33	28 vi	5 vii	7 vii	4 viii	Died.	..	7	2	28		
,, 34	,,	,,	,,	,,	14 viii	♀	7	2	28	8*	
,, 35	,,	,,	,,	,,	13 viii	♂	7	2	28	7*	
,, 36	,,	,,	,,	,,	,,	♂	7	2	28	7*	
,, 37	,,	,,	,,	5 ix	12 ix	♀	7	2	60	7	
,, 38	,,	,,	,,	,,	Died.	..	7	2	60		
,, 39	,,	,,	,,	,,	10 ix	♂	7	2	60	5	Crippled.
,, 40	,,	,,	,,	,,	12 ix	♂	7	2	60	7	Crippled.

* Counted by deducting 2 days of cooling while I was away from home (10—12 viii).

TABLE VI.—*E. autumnaria*. Forced larvæ, forced pupæ.

No.	Sp. up.	Pupated.	Emerged.	Sex.	Days. Pupg.	Pupa.	Total.	
1	2 vi	4 vi	....	....	2			Affected by excessive heating; all but one died.
2	4 vi	6 vi *m*	....	....	2			Affected by excessive heating; all but one died.
5	6 vi *m*	7 vi *a*	27 vi *m*	♂	1	20	21	Affected by excessive heating; all but one died.
6	6 vi *m*							Affected by excessive heating; all but one died.
7	6 vi *m*	8 vi *a*	....	....	2			Affected by excessive heating; all but one died.
11	6 vi *a*							Affected by excessive heating; all but one died.
12	6 vi *a*							Affected by excessive heating; all but one died.
15	8 vi *a*							Affected by excessive heating; all but one died.
19	9 vi *a*							Affected by excessive heating; all but one died.
20	9 vi *a*							Affected by excessive heating; all but one died.
21	10 vi *a*							Affected by excessive heating; all but one died.
23	11 vi *m*	12 vi *a*	27 vi *a*	♂	1½	15	16½	
24	,, *a*	14 vi *m*	26 vi *a*	♀	2½	12½	15	
25	12 vi *a*	14 vi *m*	29 vi *m*	♂	1½	15	16½	
26	12 vi *a*	14 vi *a*	26 vi *a*	♀	2	12	14	
27	12 vi *a*	14 vi *m*	26 vi *a*	♀	1½	12½	14	
28	12 vi *a*	14 vi *a*	30 vi *m*	♂	2	15½	17½	
29	12 vi *a*	14 vi *a*	29 vi *a*	♂	2	15	17	
30	13 vi *a*	15 vi *m*	27 vi *a*	♀	1½	12½	14	
31	13 vi *a*	15 vi *m*	27 vi *a*	♀	1½	12½	14	
32	13 vi *a*	15 vi *a*	30 vi *a*	♂	2	15	17	
33	13 vi *a*	16 vi *m*	1 vii *m*	♂	2½	15	17½	
34	18 vi *m*	20 vi *a*	2 vii *a*	♀	2½	12	14½	Pl. fig. 8.
35	19 vi *m*	20 vi *a*	3 vii *m*	♀	1½	12½	14	
36	19 vi *m*	21 vi *m*	5 vii *a*	♂	2	14½	16½	Pl. fig. 7.
37	19 vi *m*	20 vi *a*	3 vii *m*	♀	1½	12½	14	
38	19 vi *m*	20 vi *a*	3 vii *a*	♀	1½	13	14½	

Table VII.—*E. autumnaria.* Forced larvæ, cooled pupæ.

No.	Sp. up.	Pupated.	Cooled.	Taken out.	Emerged.	Sex.	Days.					
							Pup.	Ord.	Cool	Ord.	Tot.	
3	5 vi	8 vi *a*	10 vi *a*	8 vii	16 vii *a*	♀	3	2	28	8	41	Pl. fig. 10
4	5 vi	8 vi *a*	10 vi	8 vii	19 vii *e*	♂	3	2	28	11	44	Pl. fig. 9
8	6 vi *m*	9 vi *a*	10 vi	8 vii	20 vii *m*	♂	3½	1	28	12	44½	
9	6 vi *m*	9 vi *a*	10 vi	8 vii	20 vii *m*	♂	3½	1	28	12	44½	
10	6 vi *m*	9 vi *a*	10 vi	8 vii	19 vii *a*	♂	3½	1	28	11	43½	
13	6 vi *a*	10 vi *a*	12 vi *a*	10 vii	23 vii *m*	♂	4	2	28	13	47	
14	7 vi *a*	11 vi *a*	13 vi *m*	11 vii	20 vii *m*	♀	4	1½	29	9	42½	
16	9 vi *a*	Died pu	pating									
17	9 vi *a*	14 vi *m*	15 vi *m*	13 vii	22 vii *m*	♀	4½	1	28	9	42½	
18	9 vi *a*	11 vi *a*	13 vi *a*	11 vii	19 vii *e*	♀	2	2	28	8	40	Crumpled
22	10 vi *a*	15 vi *m*	16 vi *m*	14 vii	23 vii *e*	♀	4½	1	28	9	42½	

Note to Table VII.—As soon as the larvæ were found to be spinning-up they were removed from the forcing-box to the ordinary temperature of the room, and were "cooled" a day or two after pupating.

Table VIII.—*E. autumnaria.* Sleeved as larvæ, ordinary temperature as pupæ.

No.	Sp. up.	Pupated.	Cooled	Ord. temp.	Forced.	Ord. temp.	Cooled	Ord. temp.	Emerged	Sex.
7	21 vii	24 ? vii	10 viii	12 viii	13 viii	16 viii	......	....	16? viii	♂
11	25 vii	26? vii	,,	,,	,,	....	16 viii	25 viii	27 viii	♂
12	25 vii	26? vii	......	26 vii	....	....	,,	,,	31 viii	♂
13	....	26? vii	10 viii	12 viii	13 viii	....	......	....	14 viii	♂
15	26 vii	27 vii *a*	......	15 viii	....	....	......	....	16 viii	♀
21	30 vii *a*	30 vii *e*	......	30 vii *e*	....	....	16 viii	25 viii	1 ix	♂
22	30 vii *a*	1 viii *m*	......	....	....	....	,,	,,	1 ix	♀

Note.—The reason of the forcing and cooling was that I was away from home from 10th to 12th August, and again from 16th to 25th August, and measures had to be taken to prevent the emergence of the moths during my absence. Upon a careful examination, and a comparison with some bred in 1888 from larvæ and pupæ sleeved as larvæ, and kept at an ordinary temperature all through the pupal period, which they closely resemble in appearance, I do not think the forcing or cooling has affected their appearance. Neither forcing nor cooling was in any case applied till the pupæ had been 15 days at the ordinary temperature. (Nos. 12 and 15 are figs. 1 and 2 in the Plate).

Table IX.—*E. autumnaria.* Sleeved as larvæ, forced as pupæ.

No.	Sp. up.	Forced.	Pupated.	Emerged	Sex.	Days.			
						Pupg.	Forced	Total.	
1	13 vii	13 vii	14 vii *e*	27 vii *a*	♀	1½	13	14½	
2	13 vii	13 vii	15? vii	29 vii *m*	♂	2?	14	16?	
8	,,	25 vii	....	6 viii *a*	♀	2?	12	14?	Pl. fig. 4
11	....	26 vii	Pupa.	7 viii *m*	♂	2?	12	14?	
16	26 vii	26 vii	27 vii *a*	7 viii *m*	♀	1½	11	12½	
17	,,	,,	27 vii *a*	9 viii *a*	♂	1½	13	14½	
18	,,	,,	27 vii *e*	10 viii *m*	♂	1½	13½	15	Pl. fig. 3
20	,,	,,	28 vii *e*	9 viii *a*	♀	1½	12	13½	

TABLE X.—*E. autumnaria.* Sleeved as larvæ, forced as pupæ, and afterwards iced.

No.	Sp. up.	Forced	Pupated.	Cooled.	Iced.	Taken out.	Emerged	Sex.	Days.				
									Pupg.	Forced	Iced.	Ordy.	
5	21 vii	21 vii	23 vii *a*	30 vii *m*	30 vii *a*	27 viii	7 ix	♀	2	7	28	11	Crippled.
6	,,	,,	23 vii *e*	30 vii *m*	,,	,,	Died.	..	2½	7	28		
9	25 vii	25 vii	27 vii *m*	....	3 viii	14 ix	Died.	..	2	7	42		
10	,,	,,	27? vii	....	,,	,,	Died.	..	2?	7	42		

TABLE XI.—*E. autumnaria.* Sleeved as larvæ, cooled or iced as pupæ.

No.	Sp. up.	Cooled.	Pupated.	Iced.	Taken out.	Emerged	Sex.	Days.					
								Pupg.	Cooled	Iced.	Ordy.		
3	16 vii	16 vii	28 vii	29 vii	26 viii	18 ix *a*	♂	12	1	28	23		
4	,,	,,	26 vii	27 vii	25 viii	19 ix *a*	♂	10	1	29	25	Crippled.	
19	26 vii	26 vii	9 viii	......	6 ix	22 ix *m*	♀	14	42	..	16		Pl. fig. 6
23	30 vii	30 vii	1 viii	1 viii	15 ix	13 x *m*	♀	2	..	45	28	Crippled.	
24	,,	,,	5 viii	6 viii	,,	13 x *a*	♀	6	1	40	28	Crippled.	
25	,,	,,	10 viii	......	,,	10 x *a*	♂	11	36	..	25	Crippled.	
26	,,	,,	1 viii	......	,,	4 x *e*	♂	2	45	..	19		Pl. fig. 5
27	30 vii	2 viii	2 viii	......	29 ix	12 x *e*	♂	3	58	..	13	Crumpled.	
28	2 viii?	,,	,,	......	11 x	Died.	..	..	70				
29	,,	4 viii	4 viii	......	13 x	21 x *m*	♀	2	70	..	8	Crippled.	
30	,,	,,	,,	......	21 x	Died.	..	2	78				
31	2 viii	5 viii	5 viii	......	,,	Died.	..	3	77				
32	7 viii	12 viii	10? viii	......	,,	29 x	♀	3	72	..	8	Crippled.	
33	8 viii	13 viii	13 viii	......	,,	Died.	..	5	69				
34	12 viii	16? viii	16? viii	......	2—4 ix	10 ix	♀	4?	48?				
35	17? viii	6 ix	21? viii	......	21 x	Died.	..	4?	45?	..	16?		

Notes to Table XI.—Nos. 3, 4, 19, 23, 24, and 25 were cooled as pupating larvæ, the others after pupating, sometimes a few minutes after.

Table XII.—*E. alniaria* (*tiliaria*), forced as larvæ, cooled as pupæ.

No.	Sp. up.	Pupated.	Cooled.	Taken out.	Emerged	Sex.	Days. Pupg.	Days. Cooled	Days. Ordy.
6	5 vi	8 vi *a*	10 vi	8 vii	21 vii *m*	♂	3	28	13
7	6 vi *a*	10 vi *a*	11 vi *a*	9 vii	died		4		
8	,,	,,	,,	,,	24 vii *m*	♂	4	28	15
9	,,	,,	,,	,,	died		4		
10	,,	,,	,,	,,	19 vii *a*	♀	4	28	10
13	9 vi *a*	died							
14	,,	13 vi *a*	14 vi *a*	12 vii	died		4	28	
15	,,	,,	,,	,,	22 vii *a*	♀	4	28	10

Table XIII.—*E. alniaria* (*tiliaria*), sleeved as larvæ, forced as pupæ.

No.	Sp. up.	Pupated.	Forced.	Emerged	Sex.	Days. Pupg.	Days. Ordy.	Days. Forced
5	3 vii	4—6 vii	7 vii	17 vii *m*	♂	2?	2?	10?
6	,,	,,	,,	18 vii *e*	♀	2?	2?	11?
7	5 vii	6 vii	7 vii	19 vii *m*	♂	1?	1?	12?
8	,,	7 vii	7 vii	20 vii *m*	♂	2?	0	13?
9	5 vii	....	8 vii	20 vii *m*	♂	3?	1	12?
10	10 vii	....	10 vii	died				
12	13 vii	15 vii *a*	13 vii	28 vii	♂	2	0	13
15	....	....	16 vii	31 vii *a*	♂	......	......	15
25	....	19 vii ?	19 vii	3 viii *m*	♂	......	......	15
26	....	21 vii ?	21 vii	5 viii *m*	♀	......	......	15
27	....	....	21 vii	died				

Table XIV.—*E. alniaria* (*tiliaria*), sleeved as larvæ, ordinary temperature as pupæ.

No.	Sp. up.	Pupa, found.	Emerged.	Sex.
1	....	26 vi	14 vii	♂
2	....	3 vii	23 vii	♀
3	....	3 vii	23 vii	♂
4	3? vii	4—6 vii	23? vii	♂
11	13 vii	....	14 viii *m*	♂

TABLE XV.—*E. alniaria* (*tiliaria*), sleeved as larvæ, forced, cooled, or iced as pupæ.

No.	Sp. up.	Cooled.	Forced.	Pupated.	Iced.	Taken out.	Emerged	Sex.	Pupating.	Pupa, days.			
										Ord.	Iced and Cooled	Ord.	
13	16? vii	....	....	Pupa	21 vii	2 ix	died	....	....	5	......		
14	16? vii	16 vii	....	Pupa	21 vii	2 ix	died	....	....	5	43		
16	16 vii	16 vii	....	20 vii	....	10 ix	23 ix *a*	♂	4	52	......		Crippled.
17	,,	,,	....	30 vii	30 vii	28 viii	....	♂	14	....	29		
18	....	17 vii	....	Pupa	19 vii	15 ix	13 x *e*	♂	....	2	58	28	Crippled.
19	....	,,	....	Pupa	,,	,,	12 x *m*	♂	....	2	58	27	Subdiaphanous.
20	....	,,	....	Pupa	,,	,,	died	....	....	2	58		
21	17 vii	19 vii	....	19 vii	20 vii	31 viii	28 ix *m*	♂	2	....	42	28	
22	,,	,,	....	,,	,,	,,	29 ix *a*	♂	2	....	42	27	Crippled.
23	,,	21 vii	....	21 vii	22 vii	15 ix	17 x *m*	♂	4	....	55	32	Crippled.
24	19 vii	16 viii	....	23? vii	....	25 viii	29 viii	♂	4?	24?	9	4	
28	25 vii	16 viii	....	28 vii *m*	....	25 viii	28 viii	♀	3	19	9	3	
29	27? vii	....	....	Pupa	27 vii	15 ix	16 x *m*	♂	....	....	50	31	
30	27? vii	....	....	Pupa	27 vii	15 ix	16 x *a*	♂	....	....	50	31	
31	27 vii	27 vii	....	....	....	15 ix	died						
32	,,	....	27 vii	28 vii	5 viii	2 ix	died						
33	,,	....	,,	29 vii *m*	,,	2 ix	died						
34	30 vii	30 vii	....	6 viii	....	28 viii	17 ix *m*	♂	7	....	22	20	
35	2 viii	2 viii	....	6 viii	....	11 x	died	....	4	....	36		
36	5 viii	9 viii	....	8 viii	....	15 ix	21 x *m*	♂	3	....	37	36	Crippled.

Tables XVI., XVII.—In this case a third (forced) brood of *illustraria* hatched 4 viii, "split." From 22 to 28 viii, 26 spun up, 10 males and 16 females, all perfect, between 30th Aug. and 8th Sept.; of the rest, some died and about 70 spun up, beginning 5 ix; 36 of them became living pupæ by 26th Sept., and the following tables show the subsequent treatment of these 36, and the results as to the 12 which survived :—

Table XVI.—*Illustraria* autumn pupæ, forced.

No.	Sp. up and forced.	Emerged.	Sex.	Days.		
1	9—12 ix	12 xi	♂	63	Crippled	
2	14 ix	26 xii	♂	103	Crippled	
1	12—14 ix	11 xi	♀	59	Perfect	Plate, fig. 9.
2	,,	9 xii	♀	87	Crippled	
3	,,	,,	♀	87	Crippled	
4	,,	10 xii	♀	88	Crippled	

Table XVII.—*Illustraria* autumn pupæ, warmed, then wintered (frosty weather).

No.	Sp. up and warmed.	Ord. temp.	Wintd.	Ord. temp.	Warmed.	Emerged.	Sex.	Days.						
								Warm.	Ord.	Wintd.	Ord.	Warm.		
3	12-14 ix	12 xi	27 xi	1 i	9 i	13 ii	♂	60	15	35	8	35	Fair	
4	,,	,,	,,	,,	,,	28 ii	♂	60	15	35	8	50	Crippled	
5	,,	,,	,,	,,	,,	1 i	♀	60	15	35	0	0	Fair	
6	,,	,,	,,	,,	,,	3 i	♀	60	15	35	2	0	Crippled	
7	,,	,,	,,	,,	,,	22 i	♀	60	15	35	8	13	Perfect	Pl. fig. 10
8	22 ix?	,,	,,	,,	,,	18 ii	♀	55?	15	35	8	40	Perfect	

The object of the "ordinary temperature" was to prevent a sudden change of temperature. "Warm" means a temperature of about 70°.

Table XVIII.—*Illustraria* autumn pupæ at ordinary indoor temperature (45°–55°), afterwards wintered or warmed, or both.

No.	Sp. up.	Wintd.	Ord. temp.	Warmed.	Emerged	Sex.	Days.			
							Ord.	Wintd.	Ord.	Warm.
1	26 ix	27 xi	1 i	9 i	28 i	♂	62	35	8	19
2	26 ix	....	......	29 i	9 ii	♂	....	......	125	11
3	17 ix	....	......	,,	9 ii	♂	....	......	134	11
4	26 ix	....	......	,,	11 ii	♂	....	......	125	13
5	26 ix	....	......	,,	11 ii	♂	....	......	125	13
6	26 ix	27 xi	1 i	9 i	13 ii	♂	62	35	8	35
7	26 ix	27 xi	1 i	9 i	14 ii	♂	62	35	8	36
8	28 ix	,,	,,	,,	15 ii	♂	62	,,	,,	37
9	6 x	,,	,,	,,	16 ii	♂	52	,,	,,	38
10	28 ix	,,	,,	,,	16 ii	♂	60	,,	,,	38
11	29 ix	,,	,,	,,	17 ii	♂	59	,,	,,	39
12	6 x	,,	,,	,,	23 ii	♂	52	,,	,,	45
13	26 ix	,,	,,	,,	28 ii	♂	62	,,	,,	50
14	2 x	....	......	3 iii	11 iii	♂	....	......	152	8
15	26 ix	....	......	,,	,,	♂	....	......	158	8
1	28 ix	....	......	29 i	9 ii	♀	....	......	123	11
2	14 ix	27 xi	1 i	9 i	9 ii	♀	74	35	8	31
3	15 ix	....	......	3 iii	9 iii	♀	....	......	169	6
4	2 x	....	......	3 iii	10 iii	♀	....	......	152	7
5	26 ix	....	......	3 iii	11 iii	♀	....	......	158	8

Nos. 1 and 6 to 13, ♂ and 2 ♀ (wintered) very slightly darker than the rest; No. 1, ♂, especially dark.

APPENDIX.

Descriptive summary of the effects of the temperature experiments upon the markings of the moth Ennomos autumnaria (*vel* alniaria). By W. White, F.E.S.

A.—(1) Larvæ sleeved, temperature conditions normal throughout, including (2) the pupal period.

♂. Five specimens: all *rather variable*, more or less irrorated.

♀. Two: the spotting *large in one case, finer and more sparse in the other;* both darker towards the outer margin of especially the fore wings.

These may be considered fair types of the ordinary variations occurring within a brood.

B.—(1) Larvæ sleeved, (2) pupæ forced.

♂. Four: all *paler and more ruddy* than in A, and *nearly plain* in colour, only one having rather faint spots.

♀. Four: ditto, two with faint spots.

General tendency. Plainer than type; spots lost.

C.—(1) Larvæ forced, (2) pupæ forced.

♂. Eight: of *more ruddy* appearance, and practically *unspotted*, not one possessing decided irroration; *the costal margin paler*, but the colour towards the edges of the wings appearing deeper in contrast with the general plainer coloration; the band-lines *less continuous*, and in some quite *faint;* some have local spotting more or less faint or blotchy, while in others the spotting is almost entirely absent.

♀. Nine: similar in character to the males, but the irroration is *sparse* in nearly all the specimens; edging to the marginal toothing darker.

General tendency. Ruddier than type, on account of greater freedom from superimposed markings. The sexes resemble one another more closely than normally, as in A.

D.—(1) Larvæ sleeved, (2) pupæ iced, or cooled.

♂. Five (two of them crippled): *rather darker* than A, the irrorations *both increased and more blotchy; the band-lines faint, the inner one entirely gone.*

♀. Five (two crippled, 1 crumpled, 2 perfect): variable, but fairly normal, excepting that *the inner band-line is lost in every individual but one.*

General tendency. Amplification of spotting with elimination of inner line.

E.—(1) Larvæ forced, (2) pupæ cooled.

♂. Five: *largely irrorated* with the darker fuscous marking, producing the effect of an entire darkening of the coloration, but the ground colour is really about normal; the outer band-line *very blotchy*, while the inner one is entirely lost in some in the general irroration, or it may be irrespective of it; the venation lines are rendered more distinct in most cases on account of being unspotted.

♀. Five: on the whole *the irroration is less developed than in the* ♂, *and finer*, while the *ground colour is decidedly paler and more uniform* (with the marginal shading but slightly pronounced), but the irrorations between the band and the anterior portion of the outer margin of the fore wings of most of the individuals have become merged into *a blotchy shade;* the inner band-line is *entirely lost* in all but one, which has instead a blotchy patch along that part of the field; in most specimens (*i. e.*, all but one) the dentated outline of the *hind wing* has a continuous dark line along the outer margin.

General tendency. Increased development of the irroration, with continued elimination of the inner band-line. The ground colour is warmer in both sexes than in the D form, the larvæ of which were normally conditioned.

Under each set of experiments with abnormal temperatures (excluding A) the band-lines spring directly from the costa, instead of starting with an acute angle, or hooked curve, across the first nervure, as is the case usually in the A series (see figs. 1 and 2). But, curiously enough, this angulation observable in these types is contrary to the regular specific character, as described by Mr. Stainton in his 'Manual.' Broadly speaking, the effects produced under B and C conditions are very similar, and those under D and E are similar, but in each direction there is a marked intensification of the chief characteristics in both C and E, the larvæ of which were forced.

Explanation of Plates IV. & V.

PLATE IV.

E. autumnaria.

Figs. 1, 2. Ordinary temperature as larvæ, and as pupæ, ♂ and ♀.

3, 4. Ordinary temperature as larvæ, forced as pupæ, ♂ and ♀.

5, 6. Ordinary temperature as larvæ, cooled as pupæ, ♂ and ♀.

7, 8. Forced as larvæ, and as pupæ, ♂ and ♀.

9, 10. Forced as larvæ, cooled as pupæ, ♂ and ♀.

All the specimens figured are from the same parents.

PLATE V.

S. illustraria.

Figs. 1, 2. Summer pupæ, not iced, ♂ and ♀.

3, 4. Summer pupæ, iced 16 weeks, ♂ and ♀. The specimens figured 1, 2, 3 and 4 are from the same parents. Fig. 3, though a small part of one posterior wing is imperfectly developed, is selected because it is the best illustration of darkness and change of markings *combined*. There are other specimens more extreme in both particulars.

5. Autumn pupa, forced 17 days, ♀.

6. Autumn pupa, forced 34 days, ♀.

7, 8. Autumn pupæ, not forced, spring emergence, ♂ and ♀. The specimens figured 5, 6, 7 and 8 are from the same parents.

9. Autumn pupa, forced 59 days, ♀.

10. Autumn pupa, warmed 60 days, also wintered 35 days, ♀. The specimens figured 9 and 10 are from the same parents.

11, 12. An ordinary form of the very variable summer emergence, ♂ and ♀.

13, 14. Rather dark examples of the ordinary spring emergence, ♂ and ♀.